RADIOLOGICAL WORKER STUDY GUIDE

This Manual:

1. Is a Study Guide used to prepare for the exam. associated with Part I of Radiological Worker Training.
2. Identifies the fundamental concepts of radiation, radioactive materials and radioactive contamination.
3. Presents potential biological risk associated with working with radioactive materials.
4. Specifies established dose limits for personnel who are authorized to work with radioactive materials.
5. Highlights Ames Laboratory's ALARA Program.
6. Discusses Ames Laboratory's personnel dosimetry and monitoring programs.
7. Describes ways to control radioactive contamination.
8. Identifies radiological postings and controls used at Ames Laboratory.
9. Familiarizes personnel with the types of radiological emergency alarm systems in place at the Laboratory and explains how they should react to radiological emergency alarms.

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1.0 Revision/Review Log

This manual will be reviewed once every three years as a minimum.

Revision Number	Effective Date	Contact Person	Pages Affected	Description of Revision
0	7/1/96	Hokel	All	Initial Issue
0	6/1/99	Hokel	All	Review

2.0 Purpose and Scope

2.1 Purpose

The purpose of this study guide is to assist Ames Laboratory personnel, who intend to work with radioactive materials, in preparing for and taking the “challenge examination” to become a Radiological Worker. This study guide is the first half of the total Radiological Worker Qualification Course, and is used to present the required subjects, in lieu of the 16-hour classroom course. Many research personnel prefer this method of becoming qualified, since it saves a lot of time. When an individual is confident that he/she is ready, the challenge exam will be administered by the ESH&A Office. The individual must demonstrate his/her knowledge of the material by achieving a minimum score of 80% on the examination.

When the individual successfully completes the challenge exam, he/she is then eligible to take the second half of the Radiological Worker Course, which is the practical examination, administered by the ESH&A Office Health Physics Group. Completion of Radiological Worker Training provides the participant with the necessary knowledge to work safely in areas controlled for radiological purposes using proper radiological practices, as specified in 10 CFR 835, the Ames Laboratory Radiological Protection Program (RPP), and the Ames Laboratory Site-Specific Radiological Control Manual.

2.2 Scope

This study guide applies to all activities at Ames Laboratory in which sealed and unsealed sources of radioactive materials are used, which pose the threat of radiation exposure to Ames Laboratory occupationally exposed employees, visitors, the public or the environment. Personnel required to take Radiological Worker Training are those who utilize radioactive materials in research activities or who have duties and responsibilities that require them to handle or work around radioactive materials on a frequent basis. The manual will emphasize two basic principles, which apply to every individual that may be exposed to radiation: (1) all radiation doses are to be kept ALARA, and (2) no dose to an individual shall be allowed to exceed the appropriate *individual dose limit* established by the regulations.

3.0 Prerequisite Actions and Requirements

Definitions:

Absorbed Dose: The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Activity: The rate of disintegration (transformation) or decay of radioactive material. The units of activity are the curie (Ci) and the becquerel (Bq).

administrative control level: A numerical dose constraint established at a level below the regulatory limit to administratively control and help reduce individual and collective radiation exposure.

Adult: An individual 18 or more years of age.

Airborne Radioactive Material: Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne Radioactivity Area: Any area, accessible to individuals, where the measured concentration of airborne radioactive material, above background, exceeds or is likely to exceed 10 percent of the derived air concentration (DAC) values listed in Appendix A or Appendix C to 10 CFR 835.

Administrative Control Level: A numerical dose constraint established at a level below the regulatory limit to administratively control or help reduce individual and collective radiation exposure.

As Low As Reasonably Achievable (ALARA): The approach to radiological protection to manage and control exposures (both individual and collective) to the work force and to the general public to levels as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. ALARA is not a dose limit but a process which has the objective of attaining (and maintaining, if achieved) doses as far below the applicable limits of 10 CFR 835 as is reasonably achievable.

Background Radiation: Radiation from cosmic sources; naturally occurring radioactive materials, including radon (except as a decay product of source or special nuclear material) and global fallout as it exists in the environment from the testing of nuclear explosive devices. "Background radiation" does not include radiation from radioactive material, source material, or special nuclear material.

Bioassay: The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Contamination Area: Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed the surface radioactivity values specified in Appendix D of 10 CFR 835, but do not exceed 100 times those levels.

Controlled Area: Any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive materials.

Continuous Air Monitor (CAM): An instrument that continuously samples and measures the levels of airborne radioactive materials on a "real-time" basis and has alarm capabilities at preset levels.

Declared Pregnant Worker (or Woman): A woman who has voluntarily declared to her employer (Ames Lab), in writing, her pregnancy for the purpose of being subject to the occupational dose limits to the unborn child as specified in 10 CFR 835.206 and Table 2-1, AL SSRCM. This declaration may be revoked, in writing, at any time by the declared pregnant worker.

DOE Activity: An activity taken for or by DOE or a DOE operation or facility that has the potential to result in the occupational exposure of an individual to radiation or radioactive material. The activity may be, but is not limited to, design, construction, operation, or decommissioning. To the extent appropriate, the activity may involve a single DOE facility or operation or a combination of facilities and operations, possibly including an entire site or multiple DOE sites.

Dose or Radiation Dose: The generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in this section.

Exposure: Being exposed to ionizing radiation or to radioactive material.

External Dose: That portion of the dose equivalent received from radiation sources outside the body (i.e., “external sources”).

Extremity: Hand, elbow, or arm below the elbow; foot, knee, or leg below the knee.

Eye Dose Equivalent: Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Generally Applicable Environmental Radiation Standards: Standards issued by the EPA under the authority of the Atomic Energy Act of 1954, as amended, that impose limits on radiation exposures, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

High Contamination Area: Any area, accessible to individuals, where removable contamination levels exceed or are likely to exceed 100 times the surface radioactivity values specified in Appendix D to 10 CFR 835 or those specified in Table 2-2, AL SSRCM.

High Radiation Area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 sievert) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Ionization: Ionization is the process of removing electrons from neutral atoms. If enough energy is supplied to remove electrons from the atom the remaining atom has a + charge. The positively charged atom and the negatively charged electron are called an ion pair. Ionization should not be confused with radiation. Ions (or ion pairs) can be the result of radiation exposure and allow the detection of radiation.

Ionizing radiation: Energy (particles or rays) emitted from radioactive atoms that can cause ionization. The four basic types of ionizing radiation that are of primary concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles.

Individual: Any human being who may be occupationally exposed to ionizing radiation due to their employment at Ames Laboratory or who is visiting the Laboratory.

Individual Monitoring Devices (individual monitoring equipment): Devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal ("lapel") air sampling devices.

Limits (dose limits): The permissible upper bounds of radiation doses.

Member of the Public: An individual who is not a general employee. However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Minor: An individual less than 18 years of age.

Monitoring (radiation monitoring, radiation protection monitoring): The measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Non-ionizing radiation: Radiation that doesn't have the amount of energy needed to ionize an atom is called "non-ionizing radiation." Examples of non-ionizing radiation are radar waves, microwaves and visible light.

Occupational Dose: The dose to ionizing radiation received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to radiation and/or to radioactive material. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Person: Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, government agency, any state or political subdivision of, or any political entity within a state, any foreign government or nation or other entity, and any legal successor, representative, agent or agency of the foregoing; provided that person does not include the Department or the U.S. Nuclear Regulatory Commission.

Public Dose: The dose received by a member of the public from exposure to radiation and/or to radioactive materials released by Ames Laboratory, or to another source of radiation either within Ames Laboratory's controlled areas or in unrestricted areas. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Radiation (ionizing radiation): Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in 10 CFR 835 and the AL SSRCM, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light.

Radiation Area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Radioactive material: Any material containing (unstable radioactive) atoms that emit radiation.

Radioactive contamination: Radioactive contamination is radioactive material in an unwanted place. There are certain places where radioactive material is beneficial. {It is important to note here, that exposure to radiation does not result in contamination of the worker. Radiation is a type of <u>energy</u> and contamination is a <u>material</u>.}

Radioactivity: Radioactivity is this process of unstable (or radioactive) atoms trying to become stable by emitting radiation.

Radioactive decay: Radioactive decay is the process of radioactive atoms releasing radiation over a period of time to try and become stable (non-radioactive). Also known as disintegration.

Radioactive half-life: Radioactive half-life is the time it takes for one half of the radioactive atoms present to decay. After seven half-lives the activity will be less than 1% of the original activity.

Radioactive Material Area: Any area(s), accessible to individuals, in which items or containers of radioactive material exist and the total activity of radioactive material exceeds ten times the applicable values provided in appendix E to 10 CFR 835.

Radiological area: Any area(s) within a controlled area defined as a “radioactive material area,” "radiation area," "high radiation area," "very high radiation area," "contamination area," "high contamination area," or "airborne radioactivity area" in accordance with this section.

Radiological control technician: A radiological worker whose primary job assignment involves monitoring of workplace radiological conditions, specification of protective measures, and provision of assistance and guidance to other individuals in implementation of radiological controls.

Real-time air monitoring: Measurement of the concentrations or quantities of airborne radioactive materials on a continuous basis.

Rem: The special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sievert).

Respiratory Protective Device: An apparatus, such as a respirator, used to reduce the individual's intake of airborne radioactive materials.

Sealed radioactive source: A radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material.

Survey: An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities or radioactive material present.

Whole Body: For purposes of external exposure -- head, trunk (including male gonads), arms above the elbow, or legs above the knee.

4.0 Study Topics

4.1 Radiological Fundamentals

4.1.1 <u>Atomic Structure</u>

The basic unit of matter is the atom. The central portion of the atom is the nucleus, which consists of protons and neutrons. Electrons orbit the nucleus similar to the way planets orbit our sun. The three basic particles of the atom are protons, neutrons, and electrons.

Protons:

- Protons are located in the nucleus of the atom.
- Protons have a positive electrical charge.
- The number of protons in the nucleus determines the element.
- If the number of protons in an atom changes, the element changes.

Neutrons:

- Neutrons are located in the nucleus of the atom.
- Neutrons have no electrical charge.
- Atoms of the same element have the same number of protons, but can have a different number of neutrons.
- The atoms of the same element which have the same number of protons but different numbers of neutrons are called isotopes.
- Isotopes have the same chemical properties; however, the nuclear properties can be quite different.

Electrons:

- Electrons are in orbit around the nucleus of an atom.
- Electrons have a negative electrical charge.
- Electrons determine the chemical properties of an atom.

Charge of the atom: The number of electrons and protons determines the overall electrical charge of the atom. The term ion is used to define atoms or groups of atoms that have a positive or negative electrical charge.

- No charge (neutral) - If the number of electrons equals the number of protons, the atom is electrically neutral and does not have an electrical charge.
- Positive charge (+) - If there are more protons than electrons, the atom is positively charged.
- Negative charge (-) - If there are more electrons than protons, the atom is negatively charged.

Stable and unstable atoms: Only certain combinations of neutrons and protons result in stable atoms.

- If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy in it and will not be stable.
- The unstable atom will try to become stable by giving off excess energy in the form of particles or waves (radiation). These unstable atoms are also known as radioactive atoms.

4.1.2 Definitions

Review definitions for the following words in section 3.0.

- “ionization”;
- “ionizing radiation”
- “non-ionizing radiation”
- “radioactive material”
- “radioactive contamination”
- “radioactivity”
- “radioactive decay”
- “radioactive half-life”

4.1.3 The Four Basic Types of Ionizing Radiation

The four basic types of ionizing radiation of concern in the nuclear industry are alpha particles, beta particles, gamma rays and neutron particles.

Alpha particles:

- Physical characteristics

The alpha particle has a large mass and consists of two protons, two neutrons and no electrons. (Positive charge of plus two.) It is a highly charged particle that is emitted from the nucleus of an atom. The positive charge causes the alpha particle (+) to strip electrons (-) from nearby atoms as it passes through the material, thus ionizing these atoms.

- Range

The alpha particle deposits a large amount of energy in a short distance of travel. This large energy deposit limits the penetrating ability of the alpha particle to a very short distance. This range in air is about one to two inches.

- Shielding

Most alpha particles are stopped by a few centimeters of air, a sheet of paper, or the dead layer (outer layer) of skin.

- Biological hazard

Alpha particles are not considered an external radiation hazard. This is because they are easily stopped by the dead layer of skin. Should an alpha emitter be inhaled or ingested, it becomes a source of internal exposure. Internally, the source of the alpha radiation is in close contact with body tissue and can deposit large amounts of energy in a small volume of body tissue.

Beta particles:

- Physical characteristics

The beta particle has a small mass and is negatively charged. It is emitted from the nucleus of an atom and has an electrical charge of minus one. Beta radiation causes ionization by displacing electrons from their orbits. The beta particle is physically identical to an electron. Ionization occurs due to the repulsive force between the beta particle (-) and the electron(-), which both have a charge of minus one.

- Range

Because of its negative charge, the beta particle has a limited penetrating ability. Range in air is about 10 feet.

- Shielding

Most beta particles are shielded by plastic, glass, metal foil, or safety glasses.

- Biological hazard

If ingested or inhaled, a beta emitter can be an internal hazard due to its short range. Externally, beta particles are potentially hazardous to the skin and eyes.

Gamma rays/x-rays:

- Physical characteristics

Gamma/x-ray radiation is an electromagnetic wave or photon and has no electrical charge. Gamma rays are very similar to x-rays. The only difference is in the place of origin. Gamma/x-ray radiation can ionize as a result of direct interactions with orbital electrons. The energy of the gamma/x-ray radiation is transmitted directly to its target.

- Range

Because gamma/x-ray radiation have no charge and no mass, they have a very high penetrating power. Range in air is very far. It will easily go several hundred feet.

- Shielding

Gamma/x-ray radiation are best shielded by very dense materials, such as concrete, lead or steel.

- Biological hazard

Gamma/x-ray radiation can result in radiation exposure to the whole body.

Neutron particles:

- Physical characteristics

Neutron radiation consists of neutrons that are ejected from the nucleus. A neutron has no electrical charge. Due to their neutral charge, neutrons interact with matter either directly or indirectly. A direct interaction occurs as the result of a collision between a neutron and a nucleus. A charged particle or other ionizing radiation may be emitted during these interactions, which can cause ionization in human cells. This is called *indirect ionization*.

- Range

Because of the lack of a charge, neutrons have a relatively high penetrating ability and are difficult to stop. Range in air is very far. Like gamma rays, they can easily travel several hundred feet in air.

- Shielding

Neutron radiation is best shielded by materials with a high hydrogen content, such as water or plastic.

- Biological hazard

Neutrons are a whole body hazard due to their high penetrating ability.

4.1.4 Units of Measure

Radiation:

- Roentgen (R)

The roentgen is a unit for measuring exposure. It is defined only for the effect on air. It applies only to gamma and x-rays. It does not relate biological effects of radiation to the human body.
[1 R (Roentgen) = 1000 milliroentgen (mR)]

- Rad (Radiation Absorbed Dose)

The rad is a unit for measuring absorbed dose in any material. Absorbed dose results from energy being deposited by the radiation. It is defined for any material. It applies to all types of radiation. It does not take into account the potential effect that different types of radiation have on the body.
[1 rad = 1000 millirad (mrad)]

- Rem (Roentgen equivalent man)

The rem is a unit for measuring dose equivalence. It is the most commonly used unit and pertains to man. The rem takes into account the energy absorbed (dose) and the biological effect on the body due to the different types of radiation.
[1 rem = 1000 millirem (mrem)]

Dose Rate:

<u>Dose</u> is the <u>amount</u> of radiation a person receives. <u>Dose *Rate*</u> is the <u>rate</u> at which a person receives the dose.

Examples:

a) Dose rate = dose/time
b) Dose rate = mrem/hr

Contamination/Radioactivity:

- Contamination units

1. Disintegration per minute (dpm)
2. Counts per minute (cpm)

- Radioactivity is measured in the number of disintegrations radioactive material undergoes in a certain period of time.

One curie (unit of radioactivity) =

- 2,200,000,000,000 (2.2 x 10^{12}) disintegrations per minute (dpm) or
- 37,000,000,000 (3.7 x 10^{10}) disintegration per second (dps)

For the radioactivity in air and water the curie (Ci) or microcurie (μCi) is most often used. One curie equals one million microcuries.

- 1 curie = 1,000,000 μCi

4.2 Biological Effects of Radiation

4.2.1 General Discussion

Of all the environmental factors there are, we know more about the biological effects of ionizing radiation than any other. Rather than just being able to base our information on animal studies we have a large body of information available regarding exposures to humans.

There are 4 major groups of people that have been exposed to significant levels of radiation.

- The first is some early workers such as radiologist who received large doses of radiation before the biological effects were recognized. Since that time standards have been developed to protect workers.
- The second group is the more than 100,000 survivors of the atomic bombs dropped at Hiroshima and Nagasaki. These survivors received estimated doses in excess of 50,000 mrem.
- The third group is individuals who have been involved in radiation accidents, the most notable being the Chernobyl accident.
- The fourth and largest group of individuals are patients who have undergone radiation therapy for cancer.

4.2.2 Sources of Background Radiation (See definition for "background radiation" in section 3.0)

We live in a radioactive world and always have. As human beings, we have always lived in the presence of ionizing radiation from natural background radiation since the time we were created. In fact, for the majority of us, we will be exposed to more ionizing radiation from natural background radiation than from our jobs.

- The average annual radiation dose to a member of the general population from these sources is about 360 millirem.

4.2.2.1 Natural Sources of background radiation

There are several sources of radiation that occur naturally. The radiation emitted from these sources is identical to the radiation that results from man-made sources.

The four major sources of naturally occurring radiation exposures are:

- cosmic radiation
- sources in the earth's crust, also referred to as terrestrial radiation
- sources in the human body, also referred to as internal sources
- radon

Cosmic radiation:

Cosmic radiation comes from the sun and outer space and consists of positively charged particles, as well as gamma radiation. At sea level, the average annual cosmic radiation dose is about 26 mrem. At higher elevations the amount of atmosphere shielding cosmic rays decreases and thus the dose increases. The total average annual dose to the general population from cosmic radiation is about 28 mrem.

Sources in earth's crust (terrestrial):

There are natural sources of radiation in the ground, rocks, building materials and drinking water supplies. Some of the contributors to terrestrial sources are the natural radioactive elements radium, uranium and thorium. Many areas have elevated levels of terrestrial radiation due to increased concentrations of uranium or thorium in the soil. The total average annual dose to the general population from terrestrial radiation is 28 mrem.

Sources in the human body (internal):

Elemental potassium 40 (K-40) is a radioisotope that is very widespread and common in the soil. The plants and animals that provide our sources of food all have this element in them and therefore we too have small concentrations of the isotope in our bodies. Other radioactive elements common in the human body are low levels of cesium 137 (Cs-137) resulting from the atmospheric testing of nuclear weapons,

Radon:

Radon comes from the radioactive decay of radium, which is naturally present in the soil. Because radon is a gas, it can travel through the soil and collect in basements or other areas of a home. Radon emits alpha radiation. Because alpha radiation cannot penetrate the dead layer of skin on your body, it presents a hazard only if taken into the body. Radon and its decay products are present in the air, and when inhaled can cause a dose to the lung of approximately 2400 mrem per year. This is equivalent to a whole body dose of 200 mrem.

4.2.2.2 Man-made sources of background radiation

The four major sources of man-made background radiation are:

- Medical radiation
- Atmospheric testing of nuclear weapons
- Consumer products
- Industrial uses

Medical radiation sources:

1. X-rays

X rays are identical to gamma rays; however, they originate outside the nucleus. X rays are an ionizing radiation hazard. A typical radiation dose from a chest x ray is about 10 mrem. The total average annual dose to the general population from medical x-rays is 40 mrem.

2. Diagnosis and therapy

In addition to x-rays, radioactive sources are used in medicine for diagnosis and therapy. The total average annual dose to the general population from these sources is 14 mrem.

Atmospheric testing of nuclear weapons:

Another man-made source of radiation includes residual fallout from atmospheric nuclear weapons testing in the 1950's and early 1960's. Atmospheric testing is now banned by most nations. The average annual dose from residual fallout is less than one mrem in a year.

Consumer products:

Examples include TV's, older luminous dial watches, and some smoke detectors. This dose is relatively small as compared to other naturally occurring sources of radiation and averages 10 mrem in a year.

Industrial uses:

Industrial uses of radiation include x-ray machines (radiography) used to test pipe welds, boreholes, etc.

4.2.3 Effects of Radiation on human cells

The human body is made up of many organs, and each organ of the body is made up of specialized cells. Ionizing radiation can potentially affect the normal operation of these cells.

4.2.3.1 Biological effects begin with the ionization of atoms.

- The method by which radiation causes damage to **any** material is by ionization of atoms in the material.
- The method by which radiation causes damage to **human cells** is by ionization of atoms in the cells. Atoms make up cells that make up the tissues of the body. These tissues make up the organs of which our body consists. Any potential radiation damage to our body begins with damage to atoms.
- A cell is made up of two principle parts, the body of the cell and the nucleus, which is like the brain of the cell.
- When ionizing radiation hits a cell, it may strike a vital part of the cell like the nucleus or a less vital part of the cell. This occurrence is similar to being struck by a bullet, it may strike a vital part such as your head or may strike a less vital part such as your toe.

4.2.3.2 Cell sensitivity

Some cells are more sensitive to environmental factors such as viruses, toxins and ionizing radiation. Radiation damage to cells may depend on how sensitive the cells are to radiation.

- Actively dividing cells (and non-specialized cells)

When a cell is in the process of dividing, it is less able to repair any damage. Therefore, cells in our bodies that are actively dividing are more sensitive to environmental factors such as ionizing radiation. Cells that are rapidly dividing include: Blood forming cells; the cells that line our intestinal tract; hair follicles; and cells that form sperm.

- Less actively dividing (and more specialized cells)

Cells which divide at a less rapid pace or are more specialized (such as brain cells or muscle cells) are not as sensitive to damage by ionizing radiation.

4.2.3.4 Possible Effects of Radiation on Cells

When a cell is damaged by something in its environment, such as ionizing radiation, several things can happen. The following are possible effects of radiation on cells.

1. There is no damage
2. Cells repair the damage and operate normally

The body of most cells is made up primarily of water. Therefore, when ionizing radiation hits a cell, it is most likely to interact with the water in the cell. Often the cell can repair this type of damage. Ionizing radiation can also hit the nucleus of the cell. The nucleus contains the vital parts of the cell such as chromosomes. (The chromosomes determine the cells function.) When chromosome duplicate themselves, the chromosomes transfer their information to new cells. Damage to chromosomes, although often more difficult, can also be repaired. In fact the average person repairs 100,000 chromosome breaks per day.

3. Cells are damaged and operate abnormally

We know that the human cell is very resilient and in many cases it just repairs the damage and goes about its business as mentioned above. But the damage may not be repaired or may be incompletely repaired. In that case, the cell may not be able to do its function or it may die. It is possible that a chromosome in the cell nucleus could be damaged but not be repaired correctly. This is called a mutation or genetic effect. We will discuss genetic effects when we consider chronic radiation doses.

4. Cells die as a result of the damage

At any given moment thousands of our cells are dying and being replaced by normal cells near by. It is only when the dose of radiation is very high or is delivered very rapidly that cell may not be able to repair itself or be replaced.

4.2.4 Acute and Chronic Radiation Doses

Potential biological effects depend on how much and how fast a radiation dose is received. Radiation doses can be grouped into two categories, acute and chronic dose.

We know that radiation therapy patients receive high doses of radiation in a short period of time but, generally, only to a small portion of the body (not a whole body dose). Ionizing radiation is used to treat cancer in these patients because cancer cells are rapidly dividing and sensitive to ionizing radiation. Some of the symptoms of people undergoing radiation therapy are hair loss, nausea and tiredness.

4.2.4.1 Acute radiation doses

An acute effect is a physical reaction due to massive cell damage. This damage may be caused by a large radiation dose received in a short period of time. Large doses of radiation received in a short period of time are called acute doses. The body can't repair or replace cells fast enough from an acute dose and physical effects such as reduced blood count and hair loss may occur.

Slight blood changes may be seen at acute doses of 10-25 rem (10,000-25,000) mrem but an individual would not otherwise be affected.

Radiation sickness:

At acute doses greater than 100 rem (100,000) mrem about half of the people would experience nausea (due to damage of the intestinal lining). Radiation therapy patients often receive doses in this range and above, although doses to the region of a tumor is many times higher than this.

If the acute dose to the whole body is very large (on the order of 500,000 mrem or larger) it may cause so much damage that the body cannot recover. An example is the 30 firefighters at Chernobyl who received acute doses in excess of 800 rem (800,000 mrem.) These individuals succumbed to the effects of the burns they received compounded by their radiation exposure.

After an acute dose to the whole body:

After an acute dose, damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months. Only in those extreme accidents, such as with the Chernobyl firefighters, would the dose be so high as to make recovery unlikely.

Acute doses to only part of the body:

It is possible in that radiation exposure may be only to a limited part of the body such as the hand. There have been accidents, particularly with X-ray machines, that individuals have exposed their fingers to part of the X-ray beam. In some of these cases individuals have received doses of millions of mrem to their fingers and some individuals have lost their finger or fingers. It is important for individuals who work with X-ray equipment or similar equipment to be trained in the safe use of this equipment.

Probability of an acute dose:

What is important to understand is that it takes a massive acute dose of radiation before any physical effect is seen. These acute doses have only occurred in Hiroshima/Nagasaki, a few radiation accidents, and Chernobyl. The possibility of a radiological worker receiving an acute dose of ionizing radiation on the job is extremely remote. In may areas where radioactive materials are handled, the quantities handled are small enough that they do not produce a large amount of radiation. Where there is a potential for larger exposures, many safety features are in place.

4.2.4.2 Chronic radiation doses

A chronic radiation dose is typically a small amount of radiation received over a long period of time. A typical example of a chronic dose is the dose we receive from natural background every day of our lives or the dose we receive from occupational exposure.

Chronic dose versus acute dose:

The body is better equipped to tolerate a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body also has time to replace dead or non-functioning cells with new, healthy cells. It is only when the dose of radiation is so high or is received very rapidly that the cellular repair mechanisms are overwhelmed and the cell dies before repair can occur. A chronic dose of radiation does not result in physical changes to the body such as is seen with acute doses. Because of cell repair even sophisticated analysis of the blood do not reveal any biological effects.

Genetic effects:

The biological effects of concern from a chronic dose is changes in the chromosomes of a cell or direct irradiation of a unborn child. Genetic effects refer to effects to genetic material in a cell chromosome. Genetic effects can be somatic (cancer, etc.) or heritable (future generations).

- Effects in the exposed individual or ***somatic effects*** = effects on the body

  In this case, the individual has experienced damage to some genetic material in the cell that could eventually cause that cell to become a cancer cell. An example of a somatic effect is cancer. The probability of this is very low at occupational doses.

- Heritable effects

  A heritable effect is a genetic effect that is inherited or passed on to an offspring. In the case of heritable effect, the individual has experienced damage to some genetic material in the cell that, although doesn't affect the individual, will be passed on to future generations. Heritable effects from radiation have never been observed in humans but have been observed in studies of plants and animals. This includes the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki. (These are children who were conceived <u>after</u> the atom bomb.) Studies have followed these children, their children and their grandchildren.

4.2.4.3 Factors affecting biological damage due to exposure to radiation

- <u>Total dose</u> - In general the greater the dose, the greater the biological effects.
- <u>Dose rate</u> (how fast) - The faster the dose is delivered the less time the cell has to repair.
- <u>Type of radiation</u> - Alpha radiation is more damaging than beta or gamma radiation for the same energy deposited.
- <u>Area of the body exposed</u> - In general, the larger the area of the body that is exposed, the greater the biological effects. Extremities are less sensitive than internal organs. That is why the annual dose limit for extremities are higher than for a whole body exposure that irradiates the internal organs.
- <u>Cell sensitivity</u> - The most sensitive cells are those that are rapidly dividing.
- <u>Individual sensitivity</u> - Some individuals are more sensitive to environmental factors such as ionizing radiation. The developing child is the most sensitive, and children are more sensitive than adults. In general, the human body becomes relatively less sensitive to ionizing radiation with increasing age. The exception is that elderly people are more sensitive than middle aged adults due to the inability to repair damage as quickly (less efficient cell repair mechanisms).

4.2.5 <u>Prenatal Radiation Exposures</u>

Although no effects were seen in Japanese children conceived after the atomic bomb there were effects seen in some children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki.

4.2.5.1 Sensitivity of the unborn

Cells in an unborn child are rapidly dividing which makes them sensitive to any environmental factors such as ionizing radiation.

4.2.5.2 Potential effects associated with prenatal exposures

Many chemical and physical (environmental factors) are suspected or known to cause damage to an unborn child, especially early in the pregnancy. Alcohol consumption, exposure to lead, heat from hot tubs are only a few that have been publicized lately. Some children who were exposed while in the womb to the radiation from the atomic bomb were born with low birth weights and mental retardation. It has been suggested but is not proven that exposures to the unborn may also increase the chance of childhood cancer. Only when doses exceed 15,000 mrem is there a significant increase in risk.

In an effort to be prudent, limits are established to protect the unborn child from any potential effects, which may occur from a significant amount of exposure to radiation. This exposure may be the result of exposure to external sources of radiation or internal sources of radioactive material. At present occupation dose limits, the actual risk to the unborn child is negligible when compared to normal risk of pregnancy.

4.2.6 Risks in Perspective

Because ionizing radiation can damage the cell's chromosome it is possible that through incomplete repair a cell could become a cancer cell.

4.2.6.1 Risk from exposures to ionizing radiation

- We do not know what the risks are at low levels of radiation exposure.
- No increases in cancer have been observed in individuals exposed to ionizing radiation at occupational levels but the possibility of cancer induction cannot be dismissed because an increase in cancers has not been observed. Risk calculations have been derived from individuals who have been exposed to high levels of radiation.

4.2.6.2 Comparison of risks

- Acceptance of a risk is a highly personal matter and requires a good deal of informed judgment.
- The risks associated with occupational radiation doses are considered acceptable as compared to other occupational risks by virtually all the scientific groups who have studied them.
- The following information is intended to put the potential risk of radiation into perspective when compared to other occupations and daily activities.

4.2.6.3 Table 1

Table 1 below compares the estimated days of life expectancy lost as a result from exposure to radiation and other health risks. Those estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with normal day-to-day activities that we accept.

Table 1
Average estimated days lost due to daily activities

Health Risk	Average Estimated Days Lost
Unmarried male	3500
Cigarette smoking	2250
Unmarried female	1600
Coal miner	1100
25% overweight	777
Alcohol (U.S. average)	365
Construction worker	227
Driving a motor vehicle	207
100 mrem/year for 70 years	10
Coffee	6

4.2.6.4 Table 2

Table 2 below addresses the estimated days of life expectancy lost as a result from exposure to radiation and common industrial accidents at radiation-related facilities and compare these numbers to days lost as a result of fatal work-related accidents in other occupations.

TABLE 2
Average estimated days lost in other occupations

Industry	Average Estimated Days Lost
Mining/Quarrying	328
Construction	302
Agriculture	277
Radiation dose of 5,000 rem/yr. for 50 yrs.	250
Transportation/Utilities	164
All industry	74
Government	55
Service	47
Manufacturing	43
Trade	30
Radiation accidents (deaths from exposure)	<1

Average estimate days lost was calculated by recording how old workers were when they died from they died from apparent causes, subtracting this from the normal lifespan and averaging over the population sample number.

4.3 Radiation Limits

In order to minimize the potential risks of biological effects associated with radiation, dose limits and administrative control levels have been established.

4.3.1 DOE Dose Limits and Ames Laboratory "Administrative Control Levels" (refer to definitions)

The DOE radiation dose limits are established for occupational workers based on guidance from the Environmental Protection Agency (EPA), the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Radiological Protection (ICRP).

The Facility administrative control levels for radiological workers are in some cases more conservative than the DOE limits and are established to ensure the DOE limits and control level are not exceeded and to help reduce individual and total worker population radiation dose (collective dose).

The DOE dose limits and administrative control levels are as follows:

- **Whole body**

  Definition: The whole body extends from the top of the head down to just below the elbow and just below the knee. This is the location of most of the blood-producing and vital organs.

  Just as there are limits for external exposure to radiation, there are limits for internal exposure to radiation. Internal exposure is a result of radioactive material being inhaled, ingested, and absorbed through the skin or a wound.

  Limits are based on the sum of *internal* and *external* exposure.

The DOE radiation dose limit during routine conditions is 5 rem/year. The Ames Laboratory administrative control level during routine conditions is 2 rem/year.

- **Extremities**

Definition: Extremities include the hands and arms below the elbow and the feet and legs below the knees.

The Ames Laboratory radiation dose limit for extremities during routine conditions is 50 rem/year.

- **Skin and other organs**

The Ames Laboratory radiation dose limit for skin and other organs during routine conditions is 50 rem/year.

- **Lens of the eye**

The Ames Laboratory radiation dose limit for lens of the eye during routine conditions is 15 rem/year.

- **Declared pregnant worker (unborn child)**

DOE and Ames Laboratory Policies

A female radiological worker is encouraged to *voluntarily* notify her supervisor, in writing, when she is pregnant. Ames Laboratory must provide the option of a mutually agreeable assignment of work tasks, with no loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely.

Ames Laboratory Limit

For a declared pregnant worker who chooses to continue working as a radiological worker, the following radiation dose limit will apply. The dose limit for the unborn child (during entire gestation period) is 500 mrem. Efforts should be made to avoid exceeding 50 mrem/month to the pregnant worker. If the dose to the unborn child is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the pregnancy.

- **Visitors and public**

The Ames Laboratory radiation dose limit for visitors and the public is 100 millirem/year.

4.3.2 Worker Responsibilities Regarding Dose Limits and Control Levels

It is each employees responsibility to comply with DOE and Ames Laboratory dose limits/control level as well as the Ames Laboratory administrative control levels when applicable. If you suspect that dose limits or administrative control levels are being approached or exceeded, you should notify your supervisor immediately.

4.4 ALARA Program

This section is designed to inform the student of the concept of ALARA (As Low As Reasonably Achievable). Methods for reducing both external and internal doses from radiation and radioactive material are also discussed

Even though there are dose limits and administrative control levels, we strive to keep our radiation dose well below these. Employees should always try to maintain their radiation dose As Low As Reasonably Achievable (ALARA).

4.4.1 ALARA Program

4.4.1.2 ALARA Concept

ALARA stands for **A**s **L**ow **A**s **R**easonably **A**chievable.

This concept includes reducing both internal and external exposure to ionizing radiation. The ALARA concept is an integral part of all Ames Laboratory activities that involve the use of radioactive materials or radiation-producing machines.

The implementation of the ALARA concept is the responsibility of all employees.

4.4.1.2 Management Policy

Ames Laboratory Management's policy for the ALARA program is designed to control radiation exposures to workers well below regulatory limits and that there is no radiation exposure without commensurate benefit. Also, the policy is designed to prevent unnecessary radiation exposures to workers and the public, and protect the environment.

4.4.2 Responsibilities

The Ames Laboratory Director has primary responsibility for worker health and safety and must ensure that the requirements of Laboratory policies and DOE Orders and Regulations are met. The responsibility and authority for administering the ALARA program are delegated to the Health Physics Group within the ESH&A Office. Line managers are responsible for implementing the actions necessary for an effective ALARA program. All Ames Laboratory employees and others working in Ames Laboratory space bear responsibility for following ALARA principles and procedures in their day-to-day operations. A cardinal principle of on-the-job safety is that safety is everyone's concern; this principle applies also to ALARA.

Each person involved in radiological work is expected to demonstrate responsibility and accountability through an informed, disciplined and cautious attitude toward radiation and radioactivity.

4.4.3 External Radiation Dose Reduction

The main goal of the ALARA program is to reduce external radiation doses to a level that is As Low As Reasonably Achievable.

Basic protective measures used to reduce external exposure include **minimizing time** in a field of radiation, **maximizing the distance** from a source of radiation and **using shielding** whenever possible.

4.4.3.1 Methods for **minimizing time**:

Reducing the amount of time in a field of radiation will lower the dose received by the workers.

- Pre-plan and discuss the task thoroughly prior to entering the area. Use only the number of workers actually required to do the job.
- Have all necessary tools before entering the area.
- Use mock ups and practice runs that duplicate work conditions.
- Take the most direct route to the job site.
- Never loiter in an area controlled for radiological purposes.
- Work efficiently but swiftly.
- Do the job right the first time.
- Perform as much work outside the area as possible or, when practical, remove parts or components to areas with lower dose rates to perform work.
- In some cases, the Radiological Control personnel may limit the amount of time a worker may stay in an area due to various reasons. This is known as a "stay time". If you have been assigned a stay time, do not exceed this time.

4.4.3.2 Methods for **maximizing distance** from sources of radiation:

- The worker should stay as far away as possible from the source of radiation.
- For point sources, the dose rate follows the inverse square law. If you double the distance, the dose rate falls to 1/4 of the original dose rate. If you triple the distance, the dose rate falls to 1/9 of the original dose rate.
- Be familiar with radiological conditions in the area.
- During work delays, move to lower dose rate areas.
- Use remote handling devices when possible.

4.4.3.3 Proper **uses of shielding**:

Shielding reduces the amount of radiation dose to the worker. Different materials shield a worker from the different types of radiation.

- Take advantage of permanent shielding such as non-radiological equipment/structures.
- Use shielded containment (e.g., glove boxes, etc.) when available.
- Wear safety glasses/goggles to protect the eyes from beta radiation, when applicable.

Temporary shielding (e.g. lead or concrete blocks) can only be installed when procedures are used. Once temporary shielding is installed, it cannot be removed without proper authorization.

Temporary shielding will be marked or labeled with wording such as, "Temporary Shielding - Do Not Remove Without Permission from the Health Physics Group".

Remembered that the placement of shielding may actually increase the total dose in some circumstances (e.g., man-hours involved in placement, Bremstrahlung, etc.).

4.5 Personnel Monitoring

4.5.1 External Dosimetry

External personnel radiation dosimetry is required only for adults *likely* to receive, in one year from sources external to the body, a dose in excess of the limits specified in Section 4.3, as well as individuals entering a high or very high radiation area

The Health Physics Group shall maintain a permanent record of all personnel dosimetry reports. If a report indicates and overexposure, an investigation shall be initiated to determine the cause and to suggest remedial action. Individuals determined to require radiation monitoring shall be advised annually of the worker's exposure to radiation or radioactive materials.

All personnel designated by the Health Physics Group will wear external dosimetry while on duty. Also, ring dosimeters shall be worn (as appropriate) when handling certain radioactive materials. The TLD for the whole body shall be worn between the neck and waistline in the area of the torso most likely to receive radiation exposure.

Personnel dosimeters shall be obtained from a dosimetry provider and exchanged on a quarterly frequency. At the beginning of each new quarter, the Radiological Control Technicians (RCT's) will send out new dosimeters in envelopes, which will also be used to return the old ones. If a dosimeter is lost, notify the Health Physics Group immediately at 294-7922 or 294-7926.

When not on duty, personnel shall leave their dosimeters at designated areas within their department. If a dosimeter is accidentally exposed while not wearing it, notify the RCTs to obtain a replacement. In addition, the Health Physicist must be notified immediately.

Dosimeters shall be issued only to personnel formally instructed in their use and shall be worn only by those to whom the dosimeters were issued.

Personnel shall not wear dosimeters issued by Ames Laboratory while being monitored at another site. Personnel shall guard against exposing their dosimeters to security x-ray devices, excessive heat, and medical sources of ionizing radiation.

If a dosimeter is lost, damaged or contaminated, personnel shall stop work, exit the radiological area and report the occurrence to the ESH&A Office. Reentry into the area shall not be made until a review has been conducted and management has approved the reentry.

4.5.2 Radiation Dose Records and Reporting

4.5.2.1 Records

All data used to evaluate individual doses will be recorded, including dosimeter measurement results, evaluations of non-uniform doses, dose re-constructions from lost or damaged dosimeters, and evaluations resulting from anomalous dosimeter results. All numerical data will be recorded, including zero and negative results. Dosimetry records shall be kept, as required by 10 CFR 835, for a minimum of 75 years.

All information that is necessary to review and re-calculate each evaluated dose should be recorded including uncensored data, models, assumptions, parameters, and additional measurement data as appropriate. The names of the evaluator and reviewer were and the outcome of the review should be recorded any re-evaluation of external dose performed should be documented such that a record of the preliminary and final effective dose equivalent is retained.

4.5.2.2 Reporting

An annual radiation dose report "shall" be provided to each individual monitored in accordance with 10 CFR 835.402 (10 CFR 835.801(c). The report shall be in writing and include the facility name, the name of the individual, and the individual's social security number or employee number (10 CFR 835.801(a). The report shall also include the data specified in 10 CFR 835.702(c) & 801(a).

Detailed information concerning any individual's exposure "shall" be made available to the individual upon request of that individual, consistent with the provisions of the Privacy Act (5 U.SC. 552a) (10 CFR 835.801(d)

Upon the request of an individual terminating employment, records of exposure shall be provided to the individual as soon as the data are available, but not later than 90 days after termination of employment (10 CFR 835.801(b). Monitoring results, including zero dose, should be reported to each visitor within 30 days of the end of the visit, and shall be reported no later than 90 days after the end of the visit.

4.6 Radioactive Contamination Control

This Section is designed to inform the worker of sources of radioactive contamination. It will also present methods used to control the spread of contamination.

Contamination control is one of the most important aspects of radiological protection. Using proper contamination control practices will help ensure a safe working environment. It is important for all employees to recognize potential sources of contamination as well as to use appropriate contamination prevention methods.

4.6.1 Comparison of Radiation and Radioactive Contamination

Ionizing radiation - the energy (particles or rays) emitted from radioactive atoms that can cause ionization.

Radioactive contamination - recall that radioactive material is material that contains radioactive atoms. Even when this radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard. When this radioactive material escapes its container, it is then referred to as radioactive contamination.

Radiation is an energy, contamination is a material.

4.6.2 Types of Contamination

Radioactive contamination can be fixed, removable or airborne.

- Fixed contamination - contamination that cannot be readily removed from surfaces. It cannot be removed by casual contact. It may be released when the surface is disturbed (buffing, grinding, using volatile liquids for cleaning, etc.) Over time it may "weep," leach or otherwise become loose or transferable.

- Removable/transferable contamination - contamination that can readily be removed from surfaces. It may be transferred by casual contact, wiping, brushing or washing. Air movement across removable/transferable contamination could cause airborne contamination.

- Airborne contamination - Contamination suspended in air.

4.6.3 Sources of Radioactive Contamination

Radioactive material can be spread to unwanted locations, resulting in contamination.

4.6.3.1 The following is a list of potential sources of contamination:

- Leaks or breaks in radioactive systems;
- Opening radioactive systems without proper controls;
- Hot Particles - small, sometimes microscopic pieces of radioactive material that are highly radioactive. They can cause a high, localized radiation dose if they remain in contact with skin/tissue. Hot particles may be present or generated when contaminated systems are opened or when machining, cutting, or grinding is performed on highly radioactive materials;
- Airborne contamination depositing on surfaces;
- Leaks or tears in radiological containers; such as barrels, plastic bags or boxes;
- Poor housekeeping in contaminated areas;
- Excessive motion or movement in areas of higher contamination; and
- Sloppy work practices, such as cross-contamination of tools, equipment or workers.

4.6.3.2 The following are indicators of possible contamination:

- Leaks, spills, standing water;
- Dusty, hazy air;
- Damaged radiological containers;
- Spurious or unexplained personnel contaminations at exit points to an RBA;
- Higher than normal background on personnel contamination survey devices; and
- Airborne monitor alarms.

4.6.3.3 Employee response to indicators of possible contamination.

It is very important for each employee to have a basic knowledge of what should be done if indicators of possible contamination are found in the Laboratory. Although it is virtually impossible to list or anticipate <u>all</u> potential circumstances that may be encountered, the following should give appropriate guidance for most situations that may be encountered at Ames Laboratory:

A. Major spills, involving Radiation Hazards to Personnel:

- Notify all persons not involved in the spill to vacate the room or area at once. Limit the movement of displaced persons to confine the spread of contamination until they are monitored;
- If the spill is liquid and the hands are protected, right the container; otherwise, use long tongs;
- If the spill is on the skin, immediately flush thoroughly and monitor;
- If the spill is on clothing, discard outer or protective clothing at once, monitor, and decontaminate;
- Turn off fans; try to avoid creation of airborne contamination;
- Vacate the room but take care not to track or spread contamination;
- Notify the HP as soon as possible;
- Take immediate steps to decontaminate personnel involved, as necessary;
- Decontaminate the area (personnel involved in decontamination must be adequately protected). Heath Physics Group personnel will direct decontamination;
- Monitor all persons involved in the spill and cleanup operations;
- Collect bioassay samples as necessary;
- Permit no person to resume work in the area without the approval of Heath Physics Group personnel; and
- A complete history of the accident and subsequent activity must be submitted to Heath Physics Group personnel.

B. Minor Spills, Involving No Radiation Hazard to Personnel

- Notify all other persons in the room and area at once;
- Survey people before they become dispersed, and change clothes as necessary;
- Permit only the minimum number of persons necessary to deal with the spill into the area;
- Confine the spill immediately;

  - **Liquid Spills**

    - ❑ Don protective gloves.
    - ❑ Drop absorbent paper on spill.

- **Dry spills**

  - Don protective gloves.
  - Dampen thoroughly, taking care not to spread contamination. Water may generally be used, except where chemical reaction with water would generate an air contaminant; oil should be used instead.

- Decontaminate; make a plan first; and
- A complete history of the accident and subsequent remedial or protective measures must be submitted to the HP.

C. Accidents Involving Radioactive Dusts, Mists, Fumes, Organic Vapors, and Gases

- Notify all other persons to vacate the room immediately;
- Hold breath and close air vents;
- Vacate the room. Seal off area, if possible;
- Notify the HP at once;
- Ascertain that all doors giving access to the room are closed. Post conspicuous warnings or guards to prevent accidental opening of the doors;
- Monitor all persons suspected of contamination. Proceed with decontamination of personnel as directed by Health Physics;
- Report at once to the HP all known or suspected ingestions or inhalations of radioactive materials;
- Collect bioassay samples as directed by the medical consultant;
- Have a thorough medical examination possibly whole body gamma count performed as recommended by the HP or medical consultant before permitting exposed personnel to return to radiation work;
- Evaluate the hazard and the safety devices necessary for safe reentry;
- Determine the cause of contamination and rectify the condition;
- Decontaminate the area only upon the advice of the HP;
- Perform an air survey of the area before permitting work to be resumed; and
- Submit a complete history of the accident and subsequent activities to the HP.

4.6.4 <u>Contamination Control Methods</u>

Control of radioactive contamination can be achieved by proper personnel radiological practices as listed in 4.6.3 and by using engineering controls. By controlling contamination, the potential for internal exposure and personnel contamination can be decreased.

If the presence of loose contamination is discovered, decontamination is a valuable means of control.

In some situations, this is not always possible:

- **Economical conditions**: Cost of time and labor to decontaminate location out weigh the hazards of the contamination present
- **Radiological conditions**: Radiation dose rates or other radiological conditions present hazards which far exceed the benefits of decontamination.

Preventative means of control must be initiated, such as:.

A. Preparing for contamination events ahead of time by:

- Identifying and repairing leaks before they become a serious problem;
- Establishing adequate work controls before starting jobs;
- While conducting pre-job briefs, discussing measures that will help reduce or prevent contamination spread;
- Changing out gloves or protective gear as necessary to prevent cross-contamination of equipment;
- Pre-staging areas to prevent contamination spread from work activities, such as covering piping/equipment below a work area to prevent dripping contamination onto clean(er) areas. Another example would be covering/taping tools or equipment used during the job to minimize decontamination after the job (i.e., taping up a screwdriver before use); and
- Good work practices such as good housekeeping and cleaning up after jobs.

B. Good Housekeeping" is the prime factor in an effective contamination control program. It involves the interactions of all groups within the facility. Each individual should be dedicated to “keeping his house clean" to control the spread of contamination.

- Every possible effort should be made in all operations to confine the spread of radioactive materials to the smallest possible area.
- A sound preventive maintenance program can prevent many radioactive material releases.
- Controlling and minimizing all material taken into or out of contaminated areas.
- Regardless of the precautions taken, radioactive materials will occasionally escape and contaminate an area.
- Radiological workers should always be alert for potential violations to the basic principle of contamination control; such as use of improper contamination control methods, bad work practices, basic rule or procedure violations, radioactive material releases or liquid spills.
- Radiological workers should always ensure that the proper procedures to avoid the spread of contamination are followed or implemented.

C. Engineering control methods

- Ventilation is designed to maintain airflow from areas of least contamination to areas of most contamination (e.g., clean to contaminated to highly contaminated areas). Slight negative pressure is maintained on buildings where potential contamination exists.
- High efficiency filtration (HEPA) which removes radioactive particles from the air may be used.

D. Containment

- Containment generally means using vessels, pipes, cells, glovebags, gloveboxes, tents, huts, plastic coverings, etc. to control contamination by confining it to a certain area.

E. Personnel protective equipment (PPE) measures

- If engineering methods are not adequate then personnel protective measures such as protective clothing and respiratory equipment will be used.

Protective clothing is required to enter areas containing contamination levels above specified limits to prevent contamination of personnel skin and clothing. The degree of clothing required is dependent on the work area radiological conditions and the nature of the job.

Full protective clothing generally consists of coveralls, cotton glove liners, gloves, shoe covers, rubber overshoes, and hood.

NOTE: Cotton glove liners may be worn inside `standard' gloves for comfort, but should not be worn alone or considered as a layer of protection against contamination.

Proper Use of PPE

- Inspect all protective clothing for rips, tears, holes, etc. prior to use.
- Personal effects such as watches, rings, jewelry, etc. should not be worn.
- Supplemental dosimeters (contained in plastic bags/pouches) should be worn outside the coveralls for ease of reading.
- After donning protective clothing, proceed directly from the dress-out area to the work area.
- Avoid getting coveralls "wet". "Wet" coveralls provide a means for contamination to reach the skin/clothing.
- Contact Radiological Control personnel if clothing becomes ripped, torn, etc.

Respiratory equipment

Respiratory equipment is used to prevent the inhalation of radioactive materials. This training course does not qualify a worker to wear respiratory equipment.

4.6.5 Contamination Monitoring Equipment

Contamination monitoring equipment is used to detect radioactive contamination on personnel.

Hand-held contamination monitor

- Verify the instrument is on, set to the proper scale and the audio can be heard.
- Survey hands before picking the probe up.
- Hold probe approximately 1/2" from surface being surveyed for beta/gamma and 1/4" for alpha.
- Move probe slowly over surface, approximately 2" per second.
- Proceed to survey in the following typical order:
    - head (pause at mouth and nose for approximately 5 seconds)
    - neck and shoulders
    - arms (pause at each elbow)
    - chest and abdomen
    - back, hips and seat of pants
    - legs (pause at each knee)
    - shoe tops
    - shoe bottoms
    - personal and supplementary dosimeters

- The whole body survey should take 2-3 minutes per survey instrument.
- If the count rate increases during frisking, pause for 5-10 seconds over the area to provide adequate time for instrument response. Carefully return the probe to holder.
- If contamination is indicated, remain in the area and notify Radiological Control personnel.

Minimize cross contamination (such as putting a glove on a contaminated hand) while waiting for Radiological Control personnel to arrive.

4.6.6 Decontamination

Decontamination is the removal of radioactive materials from locations where it is not wanted. This does not result in the disappearance of radioactive material but involves the removal of the radioactive materials to another location.

- Personnel decontamination is normally accomplished using mild soap and lukewarm water.
- Material Decontamination is the removal of radioactive materials from tools, equipment, floors and other surfaces in the work area.

4.7 Radiological Postings and Controls

Up until now we have basically discussed some very important background radiological information and radiation dose and contamination control methods. We now take this information and see how it will apply to the actual working environment.

4.7.1 Radiological Work Permits (RWPs)

RWPs are used to establish radiological controls for entry into areas controlled for radiological purposes. They serve to inform workers of area radiological conditions, to inform workers of entry requirements into the areas, and provide a means to relate radiation doses received by workers due to specific work activities

4.7.1.1 Types of RWPs

There are two types of Radiological Work Permits depending on the radiological conditions.

- **General Radiological Work Permit**

  A General RWP is used to control routine or repetitive activities such as tours and inspections in areas with historically stable radiological conditions. It is only valid for up to one calendar year.

- **Job Specific Radiological Work Permit**

  A Job-Specific RWP is used to control non-routine operations or work in areas with changing radiological conditions. It is only valid for the duration of a particular job.

4.7.1.2 Information found on Radiological Work Permits is as follows:

- Description/location of work
- Work area radiological conditions (this information may also be determined from area radiological survey maps/diagrams or the radiological posting for that area)
- Dosimeter requirements
- Pre-job briefings (as applicable). Pre-job briefings generally consist of workers and supervisor(s) discussing various radiological aspects of the job so as to minimize radiological exposure and unplanned situations
- Required level of training for entry
- Protective clothing/equipment requirements
- Radiological Control coverage requirements and stay time controls, as applicable
- Limiting radiological condition which may void the permit
- Special dose or contamination reduction considerations
- Special personnel frisking considerations
- Technical work document and other unique identifying numbers
- Date of issue/expiration
- Authorizing signatures

4.7.1.3 Worker Responsibilities

Workers are responsible for signing on the RWP that they have read and understood the RWP prior to entering the radiological area. If you don't think that the RWP is correct or you don't understand any of the information, don't start the job and contact Radiological Control personnel or your supervisor. Workers must obey any instructions written on the permit. Never make substitutions for specified requirements.

4.7.2 Radiological Postings

4.7.2.1 Purpose

Radiological postings are used to alert personnel to the presence of radiation and radioactive materials.

4.7.2.2 Posting Requirements

Areas Controlled for Radiological Purpose will be designated with a magenta (or black) standard three-bladed radiological warning symbol on a yellow background. Additionally, yellow and magenta ropes, tapes, chains, or other barriers will be used to denote the boundaries.

- ➢ The barriers will be clearly visible from every side. Entrance points to those areas will have signs (or equivalent) stating the entry requirements, such as "Personnel Dosimeters, RWP and Respirator Required." Additionally, the radiation dose rate, contamination level and/or airborne radioactivity concentration will be included on or near each posting, as applicable.

- ➢ Before entering an area controlled for radiological purposes, read all of the signs. Since radiological conditions may change, the signs are also changed to reflect the new conditions. So, a sign or posting that you saw yesterday may be replaced with a new one the next day.

- ➢ In some cases, more than one radiological hazard may be present in the area and will be posted as such (e.g., Radiation Area, Contamination Area, Airborne Radioactivity Area.)

4.7.2.3 The following are the various areas controlled for radiological purposes.

A. **Radiological Buffer Area (RBA)** - A boundary area around other radiological areas containing greater radiological hazards such as Radiation, Contamination and Airborne Radioactivity Areas. In some cases, the boundary for the RBA and these areas may be the same.

Requirements for Entry:

- ➢ Radiological Worker Training and personnel dosimetry.

- ➢ Requirements for Working in the RBA include:

    - Always practice ALARA;
    - Eating, drinking, smoking or chewing policy;
    - Obey any posted, written or oral requirements including "Evacuate", "Hold Point" or "Stop Work" orders from Radiological Control personnel.

    NOTE:
    "Evacuate" is a verbal order issued by Health Physics Group. **"Hold points"** are specific times noted in a procedure, work permit, etc. that work must stop for Radiological Control evaluations. **"Stop Work"** orders are usually a result of:

    - ⇒ inadequate radiological controls
    - ⇒ radiological controls not being implemented
    - ⇒ radiological hold point not being observed

- Sometimes labels or tags are used to warn of specific radiological hazards. Also, radioactive material may be stored in drums, boxes, etc. and will be marked appropriately
- Hot Spot Identification
  A hot spot is a localized source of radiation or radioactive material sometimes found in equipment or piping. The radiation levels at that point are typically much higher than the surrounding area. Avoid those areas. The posting will indicate:
  "CAUTION - HOT SPOT"
- Report to Radiological Control personnel if you identify that radiological controls are not adequate or are not being followed.
- In addition, report to Radiological Control personnel if you see any unusual conditions such as leaks or spills, dusty, hazy air, and alarming Radiological Control instrumentation
- Be aware of changing radiological conditions. Make sure that your activities don't create radiological problems for others and be alert that their activities may change the radiological conditions where you are.

<u>Requirements for Exiting ALL Radiological Areas</u>

- Monitoring requirements for exiting controlled areas depend on the conditions of the area.
- Workers must monitor for contamination in accordance with instructions posted at the exit before entering a clean area. This requirement only applies when there is a Contamination, High Contamination or Airborne Radioactivity Area within the RBA.
- Personal items, such as notebooks, papers, flashlights, etc. must also be monitored for contamination and are subject to the same monitoring requirements as the person carrying them.
- Personnel frisking shall be performed prior to washing or showering.

B. **Radiation Area**

An area where radiation dose rates are > 5 mrem/hr but ≤ 100 mrem/hr. The postings/signs will indicate for example: "CAUTION, RADIATION AREA" "TLD Required for Entry"

<u>Requirements for Entry</u>

➢ Radiological Worker Training and possibly a worker signature on the RWP.

➢ The two basic requirements for working in a radiological area are: 1.) don't loiter and 2.) practice ALARA. If unanticipated elevated radiation levels are indicated as identified by off scale dosimeter, radiological alarms or other indicators:

- Stop work;
- Alert others;
- Immediately exit the area; and
- Notify Radiological Control personnel

C. **High Radiation Area**

An area where radiation dose rates are > 100 mrem/hr but ≤ 500,000 mrem/hr (more accurately, 500,000 m<u>rad</u>/hr**). The postings and signs may indicate, for example: "DANGER, HIGH RADIATION AREA" - TLD, Supplemental Dosimeters and RWP Required for Entry"

** Any dose > 450,000 mrem is usually referred to in rads, since 50% of a population will die with greater than 450,000 exposure and rems refer to biological damage to man. After 450,000 rem the designation of rem doesn't have any meaning as far as damage to human tissue, so it goes back to rad.

D. **Very High Radiation Area**

An area where radiation dose rates are >500,000 mrem/hr. (mrad/hr) The postings/signs will indicate: "GRAVE DANGER - VERY HIGH RADIATION AREA" "Special Controls Required for Entry"

~~Entry requirements~~

➢ Ffor High Radiation Area and Very High Radiation Area are Radiological Worker II Training and a worker signature on a job specific RWP. The following requirements also apply:

- Personnel and supplemental dosimeters;
- Survey meters or dose rate indicating device;
- Access points will be secured by control devices, locks, etc.; and
- Additional requirements where dose rates are > 1 rem/hr.
    - ⇒ determination of worker's current exposure
    - ⇒ pre-job brief, as applicable
    - ⇒ Radiological Control coverage

Requirements for working in a Radiation Area also apply when working in High and Very High Radiation Areas.

E. **Contamination Area**

An area where contamination levels exceed specific limits. The posting/signs may indicate, for example: "CONTAMINATION AREA" "RWP Required For Entry"

F. **High Contamination Area**

An area where contamination levels are greater than the Contamination Area. The posting/signs may indicate, for example: "DANGER, HIGH CONTAMINATION" "RWP Required For Entry"

G. **Fixed Contamination Area**

An area or equipment with no removable contamination but contains fixed contamination levels exceeding specified limits. The postings/signs may indicate, for example: "CAUTION, FIXED CONTAMINATION"

H. **Soil Contamination Area**

An area where surface or subsurface contamination levels exceed specified limits. A Soil Contamination Area may be located outside an RBA. The posting/signs may indicate, for example: "CAUTION, SOIL CONTAMINATION AREA"

Additionally, the postings/signs may include warnings, such as: "CONSULT WITH RADIOLOGICAL CONTROL BEFORE DIGGING" or "SUBSURFACE CONTAMINATION EXISTS"

I. **Airborne Radioactivity Area**

An area where airborne radioactivity exceeds specified limits. The postings/signs may indicate, for example: "CAUTION, AIRBORNE RADIOACTIVITY AREA", "RWP Required For Entry"

J. **Radioactive Materials Area**

An area that is established to indicate areas where radioactive materials are used, handled or stored. This posting will not be required when radioactive materials are inside Contamination or Airborne Radioactivity Areas.

Radioactive material, in this case, generally consists of equipment, components and materials which have been exposed to contamination or have been activated. Sealed or unsealed radioactive sources are also included.

The postings/signs will indicate: "CAUTION, RADIOACTIVE MATERIALS AREA".

<u>Requirements for entry/exit</u>

- Entry requirements into a Radioactive Materials Area where the whole body dose rate exceeds 5 mrem/hour or contamination levels exceed specified limits will be the same as for entry into a Radiation Area or Contamination Area, depending on the radiological hazard present.
- The following posting will be used designate equipment or components with actual or potential contamination "CAUTION, INTERNAL CONTAMINATION" or "CAUTION, POTENTIAL INTERNAL CONTAMINATION"

K. **Underground Radioactive Materials Area**

An area that is established to indicate areas that may contain underground items. Examples include:

- Pipelines
- Radioactive cribs
- Covered ponds
- Ditches

The postings/signs may indicate: "UNDERGROUND RADIOACTIVE MATERIALS"

4.7.2.4 Requirements for entry into Contamination Areas and Airborne Radioactivity Areas (Fixed Contamination Areas are exempt from these requirements. Soil contamination area requirements are site specific).

- Radiological Worker II Training
- Personnel dosimeters
- Worker signature on the RWP
- Protective clothing/equipment as required by the RWP
- A pre-job briefing for High Contamination Area and Airborne Radioactivity Area

4.7.2.5 Requirements for working in Contamination areas and Airborne Radioactivity areas include:

- Avoid unnecessary contact with contaminated surfaces
- Secure hoses and cables to prevent them from crossing in and out of contamination area
- When possible, wrap or sleeve materials, equipment and hoses
- Place contaminated tools, equipment, etc. inside plastic bags when work is finished
- DO NOT touch unexposed skin surfaces. Highly contaminated material left on the skin for an extended period of time can cause a significant localized dose to the skin.
- Avoid stirring contamination up, it could become airborne.
- Smoking, eating or chewing is not allowed in Contamination, High Contamination and Airborne Radioactivity Areas.

- Exit immediately if a wound occurs.

4.7.2.6 Requirements for exiting Contamination areas and Airborne Radioactivity areas include:

- Exit only at the step-off pad. A step-off pad provides a "barrier" between contaminated and other areas to prevent or control the spread of contamination between areas.
- If more than one step-off-pad is used, the final step-off-pad is "clean" and is outside the exit point and is adjacent to the boundary.
- Remove protective clothing carefully.
- Perform a whole body survey. If contamination is indicated: stay in the area, notify Radiological Control personnel, and take actions to minimize cross-contamination (e.g., put a glove on a contaminated hand).
- After exiting and monitoring yourself, it is a good radiological practice to wash your hands prior to eating, drinking, chewing, applying make-up, etc.
- Equipment/material monitoring requirements

4.7.3 Responsibilities of Workers With Regard to Postings, Signs, and Labels

It is each worker's responsibility to read and comply with all the information identified on radiological postings, signs and labels.

4.7.3.1 Disregarding any of these or removing/relocating them without permission can lead to:

- unnecessary or excessive radiation exposure and/or
- personnel contamination.

4.7.3.2 Disciplinary consequences of disregarding radiological postings, signs and labels

If any type of material used to identify radiological hazards is found outside an area controlled for radiological purposes, it should be reported to Radiological Control personnel immediately. Failure to report radiological hazards in a timely manner could result in disciplinary actions against the individual.

4.8 Radiological Emergencies

Various radiological monitoring systems are used to warn personnel if abnormal radiological conditions exist. It is very important that employees become familiar with these alarms to prevent unnecessary exposure to radiation and contamination.

4.8.1 Emergency Alarms and Responses

Equipment that monitors for abnormal radiation exposure levels and airborne contamination levels are placed in strategic locations throughout facilities. It is essential for the worker to be able to identify the equipment and alarms and respond appropriately to each.

At Ames Laboratory there are area monitors in some of the analytical x-ray laboratories, which are equipped with visual and audible alarms. The purpose of these alarms is to monitor for scattered x-ray radiation in the laboratories and alert occupants of the area if the levels get too high. In the event that one of these monitors alarms, workers should stop work activities, immediately exit the area, and notify ESH&A Office Health Physics Group at 294-7922, 294-7926 or 294-2153. Health Physics Group personnel will evaluate the cause of the alarm, and for true alarms, calculate the exposure rate.

Occasionally, continuous air monitors (CAMs) are utilized to monitor potential airborne radioactivity. Although these alarms are rarely used, workers should be aware if one is in use in their work area(s) and follow the same response for area monitors, as specified above, if the CAM alarms.

4.8.2 Disregard for Radiological Alarms

Disregarding any of these radiological alarms may lead to:

- Possible excessive personnel exposure
- Unnecessary spread of contamination
- Disciplinary action

4.8.3 Radiological Emergency Situations

Working in a radiological environment requires more precautionary measures than performing the same job in a non-radiological setting. This premise holds true if an emergency arises during radiological work.

Employees may be required to respond to situations in which:

- Personnel injuries in areas controlled for radiological purposes;
- Immediate exit from an area controlled for radiological purposes is required; or
- The Ames Laboratory administrative emergency dose limits have been exceeded. Under normal circumstances, the Ames Laboratory dose limits will not be exceeded, however, employees need to know emergency procedures in case of possible exposure.

4.8.4 Considerations in Rescue and Recovery Operations

In extremely rare cases emergency exposure to high levels of radiation may be necessary to rescue personnel or protect major property.

Rescue and recovery operations that involve radiological hazards can be a very complex issue with regard to the control of personnel exposure. The type of response to these operations is generally left up to the officials in charge of the emergency situation. The official's judgment is guided by many variables which include determining the risk versus the benefit of the action, as well as how to involve other personnel in the operation.

If the situation involves a substantial personal risk, volunteers will be used. The use of volunteers will be based on their age, experience, and previous exposure. The Ames Laboratory emergency limits for these personnel are as follows:

- Protecting major property where the lower dose limit of 5 rem is not practicable - 10 rem;
- Lifesaving or protection of large populations where the lower dose limit is not practicable - 25 rem; and
- Lifesaving or protection of large population - only on a voluntary basis to personnel fully aware of risks involved - greater than 25 rem